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Discomfort, performance degradation, and increased health risk have been associated with prolonged exposures to vibration occurring in the operation of civilian and military air, ground, and water vehicles. While an increasing number of females are selecting these occupations, the existing vibration standards and exposure limits are based on the male population. The objective of this study was to compare the biodynamic responses of females and males exposed to whole-body vibration. Seating configurations included the rigid seat and two military aircraft seat cushions. This progress report presents the results for the period 1 Dec 94 - 1 Aug 95 which includes a comparison of the resonance behaviors observed in the driving-point impedance and chest transmissibility measurements. While the frequency location of the peak or primary response (4 and 8 Hz) was not significantly affected, the peak impedance magnitude results indicated that the female responses were significantly less than the male responses and could not be attributed to differences in body weight alone. The chest transmissibility results were more variable but there was a tendency for the horizontal chest motion to be lower and the vertical chest motion to be higher in the females as compared to the males. The cushions increased the transmission of vibration in the majority of subjects with the smaller females being the most sensitive to cushion effects.

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INTRODUCTION

The operation of ground, air, and water vehicles can expose both civilian and military occupants to adverse and prolonged periods of whole-body vibration. These exposures have been associated with discomfort, performance degradation, and increased health risk (1, 2, 3, 4, 5, 6, 7). While occupations requiring the operation of heavy equipment and military air and ground vehicles have historically been dominated by males, an increasing number of females are choosing these occupations and are at risk of vibration exposure. Current vibration standards and recommended exposure limits, however, are primarily based on data collected from the male population (8,9). Differences between male and female anatomy and anthropometry are expected to affect their biodynamic response characteristics during vibration exposure raising questions about applying current vibration standards to females in order to minimize discomfort, performance degradation, and health effects. There have been no definitive studies which compare the effects of whole-body vibration between males and females and which assess the risk of the smaller female to the adverse effects of prolonged vibration exposure. A study recently conducted at the Armstrong Laboratory used female and male military personnel to evaluate the effects of several military aircraft seat cushions on the transmission of vibration in the human body. The ultimate goal was to recommend cushion design criteria which would minimize vibration transmission and contribute to improved comfort. The three female individuals who volunteered for the study were, unexpectedly, within the 5th percentile of the female population for weight, while the males were within the 50th and 95th percentile of the male population for weight. Using the driving-point impedance and transmissibility techniques, the preliminary results did show that there were significant differences between the biodynamic responses of the small females and larger males. With exposures to vertical vibration, the smaller females showed significantly higher vertical chest transmissibility but significantly lower horizontal chest transmissibility for the peak response occurring between 4 and 8 Hz as compared to the males. The driving-point impedance associated with the peak response was lower for the smaller female, as expected, due to the lower mass, however, the results were not linear (10). The cushions were also found to affect the transmission of vibration in both females and males, increasing the magnitude of the primary resonance peak located between 4 and 8 Hz (11, 12). The objective of the current study was to expand the previous study to include a broader range of body weights in both female and male subjects in order to conduct a more critical evaluation and comparison between the vibration responses of females and males. The study includes the use of three seating configurations for comparing the effects of seat cushions on vibration transmission in the body. The driving-point impedance and transmissibility techniques were used to evaluate and compare resonance behaviors in the female and male subjects. A computerized visual acuity test was also included to evaluate the effects of vibration on visual performance. This annual report presents a summary of the progress on the study for the period 1 Dec 94 to 1 Aug 95 and includes the analysis of resonance behavior observed in the impedance and chest transmissibilities at 0.06 g_{rms} acceleration.

METHODS

DATA COLLECTION AND REDUCTION

The Unholtz-Dickie electrodynamic vibration platform was used to supply the vertical vibrations. A human test seat, designed to respond as a rigid mass over the frequency range of concern, was mounted on top of the platform and included a seatback, lapbelt, and double shoulder harness. For calculating the driving-point impedance, the transmitted force of the combined seat and human was measured by three load cells located between the seat and vibration platform. Two accelerometers were attached to the seat for measuring the input acceleration magnitude and phase. Vertical and horizontal transmissibilities resulting from vertical input vibrations at the seat were calculated from acceleration measurements using two miniature accelerometers placed on the chest (at the level of the manubrium), at the upper spine region (in the vicinity of the seventh cervical vertebra on the spinous process), and on a bitebar molded with dental acrylic. Vertical acceleration was also measured on the right leg at the mid-thigh level. A ride quality meter was placed between the subject and the rigid seat or cushion and was used to measure the vertical acceleration between the subject and seating surface. The vibration signals included single sinusoidal frequencies and sum-of-sines profiles generated by combining discrete sinusoidal frequencies. The frequency range included 3 to 21 Hz in 1 Hz increments. The acceleration levels were 0.06 g_{rms} and 0.24 g_{rms} for all signals. Figure 1 illustrates the two sum-of-sines signals. A computer program was used to generate the selected frequencies or sum-of-sines signals and acceleration level, and for simultaneously collecting all transducer data. Data was collected for two seconds at 1024 Hz. A Fast Fourier Transform algorithm was used to calculate the transducer magnitude and phase difference between the sum of the three load cells and the input velocity calculated from the input acceleration at the seat. The impedance of the seat (collected separately) was subtracted from the calculated impedance to obtain the impedance of the subject. Vertical and horizontal transmissibilities were calculated as the magnitude ratio and phase difference between accelerations measured at the chest, spine, head, leg, and ride quality meter and the vertical input acceleration at the rigid seat. Each test consisted of exposing the subject to the two sum-of-sines signals and to each sinusoidal frequency between 3 and 21 Hz at one of the two acceleration levels and for one of the three seating configurations.

SEATING CONFIGURATIONS

Three seating configurations were used in the expanded effort including the rigid seat and two military aircraft seat cushions placed between the seat and subject. The first cushion (Cushion A) was obtained from a Black Hawk helicopter. The cushion is fabricated with three layers of foam with different densities. The bottom layer is made of high density plastic foam and varies in thickness from about 1 cm at the back to 6 cm at the front, providing a contoured seating surface. Air vents run from the front to the back along the inside surface. The top layer consists of polyurethane foam about 2.5 cm thick. Sandwiched between these two materials is a layer of 1.5 cm thick polyurethane material similar to the top layer but of greater density. The cushion is

covered with black lambswool and weights 920.5 gm. The second cushion (Cushion B) was a prototype cushion designed for use in the ACES II ejection seat. The cushion is fabricated entirely of rate-sensitive foam and is approximately 3 cm thick. The cushion is encased in a cotton material with the top and side surfaces further covered with a thick treated wool fabric. The cushion is flat and weighs 1678.5 gm.

VISUAL ACUITY

Visual acuity was measured using a modified computer software program originally developed in the Visual Displays Branch of the Human Engineering Division, Crew Systems Directorate, Armstrong Laboratory. The program used the Snellen E test to calculate visual acuity. Subjects used a joystick to indicate the direction of the 'E' when flashed on the screen for a designated time period. Each size figure was flashed six to eight times in a random orientation (trial). If 75% of the responses were correct, the figure size would decrease, otherwise, the size increased for the next trial. The last three trials were used to calculate the visual acuity for comparison between various vibration exposures. A baseline visual acuity test was run twice prior to and following exposure to the vibrations. Two visual acuity tests were collected for the following vibration exposures: both sum-of-sines exposures, and at the sinusoidal frequencies of 5, 10, 16, and 20 Hz.

SUBJECTS

The subject percentiles were according to body weight. In addition to the three 5th percentile (5%) females used in the previous study, two 50th percentile (50%) females and three 95th percentile (95%) females were recruited. All three 95% females participated in the rigid seat tests, however, two of the subjects had to be dropped from the study due to work conflicts and did not complete tests using the cushion seating configurations. Three 5th percentile (5%) males were included but the third subject has not completed tests using Cushion B. In addition to two of the 50th percentile (50%) males used in the previous study, a third 50th percentile (50%) male was recruited for the expanded effort. Two 95th percentile (95%) males were also recruited. Additional subjects will be recruited to complete the test matrix and will be tested as part of the on-going cushion study. Their data will be included in the Final Report. This includes one 50th percentile female, two 95th percentile females, and one 95th percentile male. During the tests, the subjects were loosely restrained by the lapbelt and shoulder harness for safety reasons. Subjects were instructed on the importance of maintaining an upright and consistent seated posture during testing. Subjects were asked to comment on any pronounced localized sensation of vibration or any sudden discomfort. The two most uncomfortable aspects of the exposures were documented. Female subjects were required to wear upper body athletic support clothing.

STATISTICAL ANALYSIS

The subjects were divided into six groups based on sex and weight percentile: 5% females, 50% females, 95% females, 5% males, 50% males, and 95% males. The preliminary results obtained previously indicated that, for subjects of the same sex and weight percentile, there were no significant differences between the primary peak impedance and transmissibility magnitude responses between subjects and the primary peak magnitude responses within a subject exposed to the three vibration signals. Therefore, the values of the peak magnitudes obtained from the three signals were combined for subjects of the same sex and weight percentile. This provided up to nine samples for each group depending on the number of subjects tested. One-Way Analysis of Variance (ANOVA) was performed on the data to determine significant differences in the magnitudes of the primary peak impedance response, the magnitude of the primary peak impedance response normalized for weight, the primary peak magnitude ratio of the horizontal chest transmissibility, and the primary peak magnitude ratio of the vertical chest transmissibility between the six groups. If significant differences were found, a *post hoc* pairwise multiple comparison test (Student-Newman-Keuls test) was used to determine the significance of differences between the various groups. For the resonance frequency (frequency location of peak response), differences of less than 2 Hz between groups were not considered significant as described in the **RESULTS**.

To compare significant differences between the primary resonance peaks for the three seating conditions, the One-Way Repeated Measures ANOVA was performed on the peak magnitude data collected for each group. Where significant differences were determined, the Student-Newman-Keuls test was used for the pairwise multiple comparisons. Differences of less than 2 Hz in the associated resonance frequency between the three seating conditions were, agina, not considered significant.

RESULTS

IMPEDANCE RESPONSE

Weight Comparison

The one-way ANOVA indicated that there were no significant differences in the mean subject weights between the 50% females and 5% males, and between the 95% females and 50% males. Figure 2 depicts the mean and standard deviation for each group and clearly illustrates the statistical result.

Group Effects on Resonance Behavior

Rigid Seat. Figure 3 illustrates the impedance frequency responses for the females and males exposed to discrete sinusoidal frequencies in the rigid seating configuration. As observed in

previous studies (13), up to four regions of peak resonance responses can be observed in the impedance magnitude profiles. The first peak region is defined between 4 and 8 Hz and is the location of the primary peak. In most cases, this peak is consistently observed and has the highest magnitude. The second region is defined between about 7 and 9 Hz. The peak observed in this region has been attributed to the dynamic response of the legs. The legs have also been considered a contributor to the third peak region located between 10 and 14 Hz. The fourth peak region has been associated with spine response. Magnitude peaks in the second, third, and fourth regions are not always observed in the impedance frequency profiles and their appearance can depend on the input acceleration level. At relatively low acceleration levels, the second peak can be of higher magnitude than the first peak. In previous studies, this was observed at 0.035 g_{rms} for males in the 50th and 95th percentile for weight. At 0.06 g_{rms}, the females showed higher responses at the second peak, particularly the 5% and 95% females. In some cases, the third peak region appears to have the highest magnitude. The first magnitude peak is primarily contributed to by the upper torso, including the shoulders and soft tissues and organs located within the chest cavity. The frequency location and magnitude of this peak was used in the comparison. Within a percentile group, there was less than ±1 Hz variation in the frequency location of this peak, regardless of the seating condition. In the majority of cases, there was a 1 Hz or less difference in the peak frequency between groups. The maximum difference was 2 Hz. Since the data was collected in 1 Hz increments, these differences were not considered significant. Figure 4 illustrates the mean and standard deviation for the frequency location of the first or primary peak for each group.

The one-way ANOVA performed on the magnitude values of the first resonance peak indicated that there were significant differences between the groups. The *post hoc* pairwise multiple comparison tests showed that, while the magnitude of the first peak was similar for the 95% females and 5% males, significant differences did occur between all other groups. Figure 5 illustrates the means and standard deviations for the six groups. The lower impedance magnitude observed for the females was expected since the impedance measurement is affected by the weight of the subject (i.e., higher impedance with higher weight), however, the 95% females weighed significantly more than the 5% males (see Figure 2). In order to evaluate differences in impedance not affected by weight, the impedance was normalized by dividing the peak magnitude response by the subject's weight. One-way ANOVA showed that there were no significant differences in the normalized impedances between subjects of the same sex, however, the ratios for the females were significantly lower than the ratios for the males. Figure 5 also illustrates the mean results for the normalized impedance and shows these differences.

<u>Cushion A</u>. The impedance profiles for Cushion A were similar to the rigid seat results, showing up to four regions of resonance with the primary peak located between 4 and 8 Hz. With the use of Cushion A, differences in the resonance frequency associated with the first impedance peak were less than 2 Hz between the six groups and were considered insignificant. The pairwise multiple comparison results for the peak magnitudes were similar to the results for the rigid seating condition: all groups showed significant differences except for the magnitude peaks observed between the 95% female and 5% male. In addition, there was no significant difference

in the magnitude peaks between the 50% and 95% females. The normalized impedance, again, showed significantly higher ratios for the males as compared to the females. There were also significant differences between the 5% and 95% females, and the 50% females and 95% females, the 95% females showing the lowest magnitude to weight ratio. It should be noted, however, that only one 95th percentile female was available for the cushion tests, providing only three data samples. Figure 6 illustrates the means and standard deviations for the impedance and normalized impedance results using Cushion A.

Cushion B. The impedance profiles generated with the use of Cushion B showed similar characteristics when compared to the rigid seat and Cushion A. With the use of Cushion B, differences in the resonance frequency associated with the first impedance peak were less than 2 Hz between the six groups and considered insignificant. The results for the peak impedance magnitude were similar to the results using Cushion A: no significant differences were noted between the 95% female and 5% male, and between the 50% female and 95% female. The results for the normalized impedances were similar to the results for the rigid seating condition: the only significant differences occurred between the females and males. Figure 7 illustrates these results.

Seating Configuration Comparison

The repeated measures ANOVA indicated that there were significant effects of the seating configuration on the magnitude of the peak impedance depending on the percentile group. The pairwise multiple comparison test showed that there were no significant effects of the seating configuration for the 95% females and 50% males. All other groups showed a significantly higher magnitude peak with the use of Cushion A as compared to the rigid seating condition. The 5% females and 95% males showed significantly higher responses with the use of Cushion B as compared to the rigid seat, with the response being significantly less than that of Cushion A for the females. Figure 8 depicts the percent change in the driving-point impedance and normalized impedance peak means for the rigid seating configuration as compared to Cushion A. An asterisk marks those changes which were significant. The figure shows that the peak impedance responses of the 5% and 50% females were the most affected by Cushion A. Cushion B produced an 8% increase in the impedance peak for the 5% female as compared to the rigid seat, half of the increase observed with the use of Cushion A.

CHEST TRANSMISSIBILITY

Group Effects on Resonance Behavior

Rigid Seat. The primary resonance peak observed for both the horizontal and vertical chest transmissibilities occurs in the same frequency region as the primary impedance peak (4-8 Hz). As mentioned previously, the chest region has been considered the major contributor to the primary resonance response in the human. Figures 9 and 10 illustrate the chest transmissibility frequency responses and indicates that there are additional peaks associated with the horizontal chest transmissibility which do appear higher than the primary peak located between 4 and 8 Hz,

particularly for the females. The additional peaks are, more than likely, the result of coupled responses between the chest and other dynamic anatomical structures and are being further investigated. Comparisons were made between the magnitude ratios of the first or primary peak located between 4 and 8 Hz. As with the impedance results, there was less than a 1 Hz difference between the location of the primary peak for the chest transmissibilities between subjects and a maximum difference of about 2 Hz between subjects from different groups. These differences were considered insignificant. Figure 11 illustrates these results.

For the peak magnitude ratios, the males showed relatively large variations within each of the three groups for the horizontal chest transmissibility. The pairwise multiple comparison indicated that the transmissibility was significantly higher in the 95% males as compared to the smaller, 5% males. The 50% and 95% females showed similar responses which were significantly higher than the response observed for the 5% females. The 50% and 95% females also showed similar responses as compared to the 5% males. The peak magnitude response for all of the female groups were significantly lower than the larger 95% males. The 50% females were similar to the 50% males. The 5% females was the only group which showed significantly lower responses than all other groups. The transmissibility was below 1.0 for the 5% females, indicating that the horizontal motion at the chest was lower than the vertical input motion. The mean transmissibility for the 95% males was approximately 150% higher than the ratio for the 5% females. Figure 12 illustrates the means and standard deviations in the horizontal chest transmissibilities for each of the groups.

In contrast to the horizontal transmissibilities, the 50% males showed a significantly lower peak magnitude than the other male groups for the vertical chest transmissibility. In addition to there being no significant differences between the female groups, all of the females showed peak magnitude means which were higher than the means for the males, however, these results were only significant for the 50% males. The largest differences in the mean transmissibilities occurred when comparing the 50% males with the 5% and 50% females; values for the males were 24% and 33% lower than the females, respectively. Figure 12 illustrates the means and standard deviations in the vertical chest transmissibilities for the six groups.

Cushion A. With the use of Cushion A, all of the male groups showed similar magnitudes for the primary peak observed for the horizontal chest transmissibility. The 5% and 95% females showed significantly higher transmissibility as compared to the 50% females. All of the male groups showed significantly higher responses than the 5% and 95% females and a higher mean response than the 50% females which was not significant. The mean ratio for the 50% males was 44% and 91% higher than the mean ratio for the 5% and 95% females, respectively. Figure 13 illustrates the means and standard deviations for the horizontal chest transmissibilities using Cushion A.

As with the rigid seating condition, the 50% males showed a lower magnitude peak for the vertical chest transmissibilities as compared to the 5% and 95% males, however, only the 95% males were significantly higher. For the females, the 5% and 95% females showed significantly higher peaks than the 50% females, and significantly higher peaks than the 5% and 50% males.

While producing mean peaks which were higher than the peaks observed for the 95% males, these results were not significant. For Cushion A, the largest difference in the mean ratios occurred between the 5% females and 50% males; the females producing a transmissibility which was 24% higher than the mean result for the males, similar to the results for the rigid seat. Figure 13 illustrates the means and standard deviations for the vertical chest transmissibilities using Cushion A.

Cushion B. With the use of Cushion B as with Cushion A, all of the male groups showed similar magnitudes for the primary peak observed in the horizontal transmissibility. The 5% and 50% females showed similar results which were significantly higher than the results obtained for the single 95% female. The mean male responses were higher than the female responses, but only significant when compared to the 5% and 95% females. The mean peak transmissibility for the 95% males was 41% higher than that of the 5% females, and 130% higher than the value for the 95% females. Figure 14 illustrates the means and standard deviations for the horizontal chest transmissibilities using Cushion B.

For the vertical chest transmissibilities in the males, the results were similar to the other two seating conditions; both the 5% and 95% males showed higher mean transmission, but only the results for the 95% males were significant. All of the females showed similar peak responses and all females showed significantly higher transmissibilities than the 5% and 50% males. The mean responses for the females were higher than the mean response for the 95% males, but the results were not significant. The 5% and 50% females mean peak responses were 22% to 25% higher than the mean peak response of the 50% males. Figure 14 illustrates the means and standard deviations for the vertical chest transmissibilities using Cushion B.

Seating Configuration Comparison

The 5% and 50% males showed that Cushion A produced a significantly higher peak than Cushion B, with no differences between the responses resulting with the use of Cushion B and the rigid seat. Except for the 95% females, all females showed a significantly higher transmissibility peak with the use of both cushion as compared to the rigid seat: all females showed that Cushion A produced a significantly higher response than Cushion B. The 95% males showed no significant effects of the seating configuration on the horizontal chest transmissibility. Figure 15 illustrates the percent change in the horizontal transmissibility with the use of both cushions as compared to the rigid seat. An asterick marks those changes which were significant. The 5% females appeared to be the most sensitive to cushion effects with 70-80% increases in transmissibility as compared to the rigid seat.

For the vertical chest transmissibilities, all groups, except the 50% females, showed significantly higher responses with the use of Cushion A as compared to the rigid seat. The 95% females showed similar responses for both cushions, while the 5% males showed similar responses for the rigid seat and Cushion B. Figure 16 illustrates the percent change with the use of cushions. An asterick marks the significant changes. For the mean vertical chest

transmissibilities, all subjects except the 50% females and 5% males showed increases of about 40% to 50% with the use of Cushion A. For Cushion B, the changes were less; the same groups showing changes of 35% or less in the mean peaks.

SUBJECTIVE RESPONSES

At the low acceleration level, there were minimal complaints about discomfort, although all subjects noticed that the vibrations between 4 and 8 Hz (particularly at 5 Hz) produced the largest body motions. Many subjects reported that the motions were felt in the whole body. One significant finding was that the females did complain that these frequencies increased motion in the chest, specifically in the breast area, and particularly for the higher accelerations level. This motion was reported to be quite uncomfortable.

VISUAL ACUITY

At the lower acceleration level, there did not appear to be much effect of vibration on visual acuity. The preliminary results for the higher acceleration level suggested that there is a decrease in visual acuity at higher frequencies above 10 Hz, but it is not clear whether differences can be delineated between the female and male subjects or between the different seating configurations. Visual acuity will be more critically assessed during evaluation of the results for the higher acceleration level.

DISCUSSION

The results for impedance clearly showed a difference between the resonance behavior of females and males for all seating configurations and that these differences were not due to differences in subject weight. However, between groups of the same sex, body weight did appear to affect differences in the resonance behavior. The results for the seating configurations also showed that Cushion A had the greatest influence on the magnitude of the first impedance peak; increasing the mean peak by a factor of 1.2 for the 5% and 50% females. Neither the group nor seating configuration appeared to significantly affect the location of the primary resonance frequency observed between 4 and 8 Hz.

Differences in the chest transmissibilities between percentile groups were not as consistent or clear as the results for impedance, however, certain trends were observed in the data. In general, the females showed lower horizontal chest motion but higher vertical chest motion as compared to the males when exposed to low level vibration. The use of cushions increased the peak chest transmissibilities at low frequencies in the majority of subjects with the smaller females appearing to be more sensitive to the seating configuration.

Differences in the subjects weights do not preclude that the transmissibilities are different. For example, given the similarity in the primary resonance frequency between the females and

males, the assumption could be made that the female is simply a scaled down version of the male, i.e., the total body weight is less, but the distribution of mass in the body is similar. In this case, all transmissibility measurements and the normalized impedance would be similar. The impedance results strongly suggested that while the total body weights were different, subjects of the same sex had a similar distribution of mass. The transmissibility data, however, indicated that this may not be the case. While there are obvious anatomical factors which should be considered in describing the differences in the biodynamic responses of females and males, the transmissibility results complicate this description by indicating that certain factors also vary between the percentile groups of the same sex. For the subject pool used thus far in this study, there were observable differences in anatomy which may have contributed to differences in the variances between the groups. The 95% males were stockier and appeared to have a higher percent of body fat as compared to the 5% and 50% males. The single 95% female used for the cushion exposures was taller than any of the subjects, her weight being distributed as height. It will be important to complete the test matrix of subjects to see if, on the average, the chest transmissibility results become more consistent. The variances between percentile groups may also become more similar, contributing to the validity of the statistical analysis. In addition, the evaluation of responses at the higher acceleration level, and the comparison of leg, head, and spine responses may provide critical information on those specific anatomical factors which significantly affect differences between the percentile groups and between the females and males.

CONCLUSIONS

The following conclusions are based on the trends observed thus far in the impedance responses and chest transmissibilities of the six percentile groups:

1. The frequency location of the primary resonance peak is not significantly different between the percentile groups or between the seating conditions.

2. Based on the impedance results, there is a significant difference between females and males which cannot be attributed to total body weight.

3. In general, the horizontal chest motions are lower but the vertical chest motions are higher in females as compared to males exposed to whole-body vibration.

4. Cushions increase the impedance magnitude at the first or primary resonance peak, and increase the transmission of vibration to the chest at the primary or first resonance peak, but the significance of these increases with respect to comfort is not clear at this time. Smaller females tend to be the most sensitive to cushion effects.

5. The impedance and chest transmissibility results and the subjective responses indicate that the distribution of mass and the stiffness and damping characteristics of the associated body structures or regions more than likely affect differences in the biodynamic responses and comfort of females and males exposed to whole-body vibration. The specific

anatomical factors responsible for these differences should become more defined following complete data analysis.

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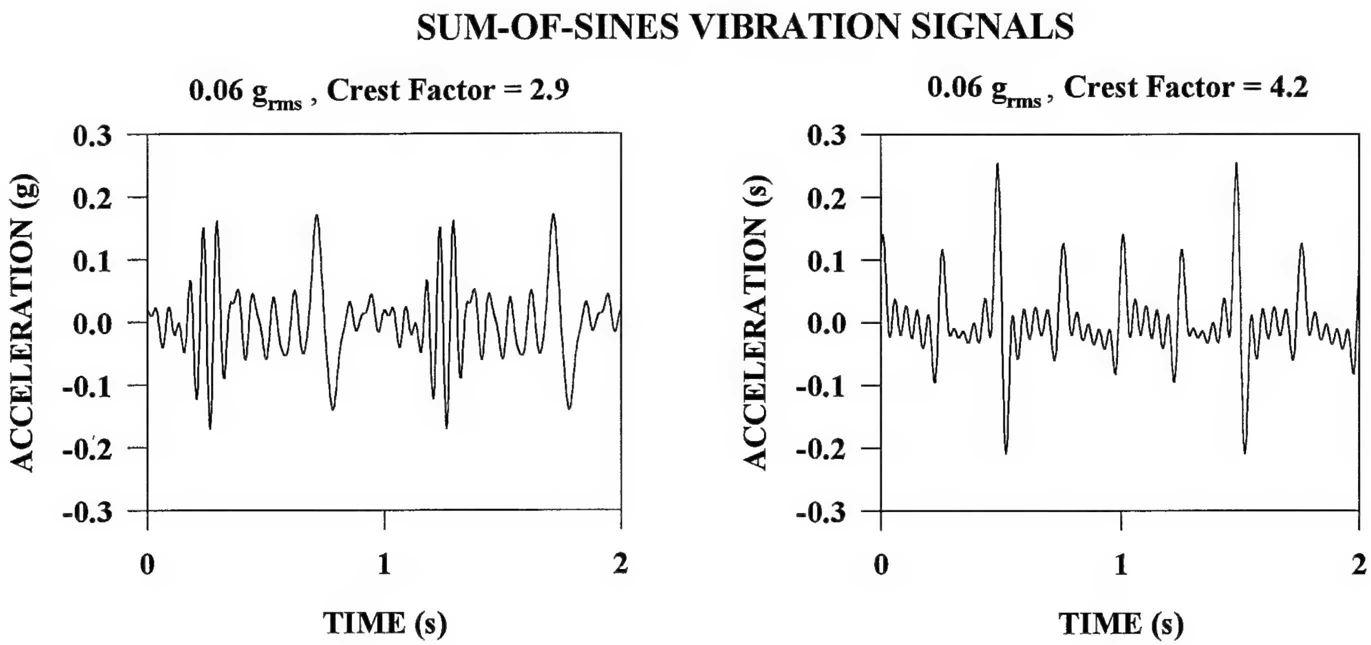


Figure 1 Sum-of-Sines Vibration Signals

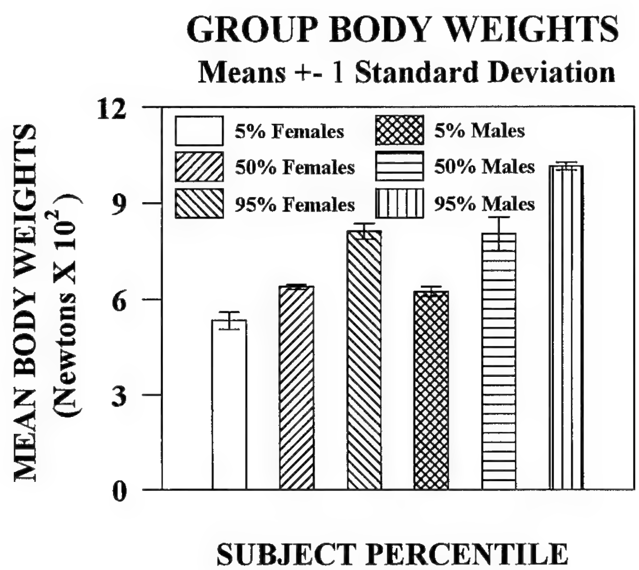
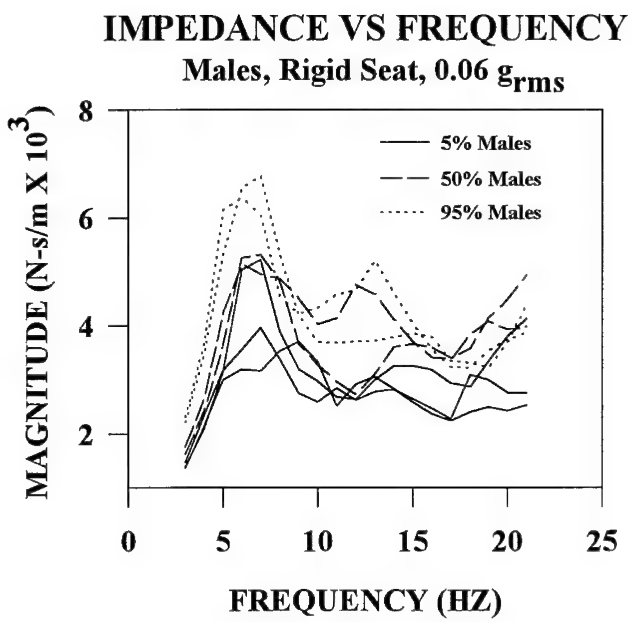


Figure 2 Group Body Weights



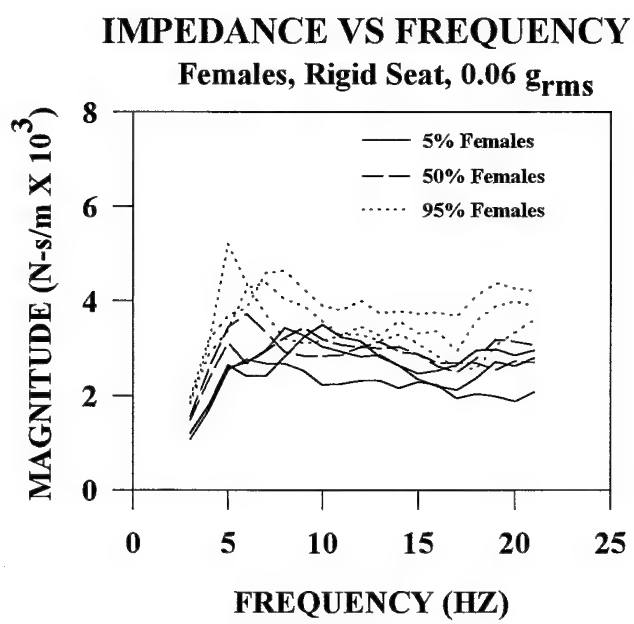


Figure 3 Impedance Frequency Responses

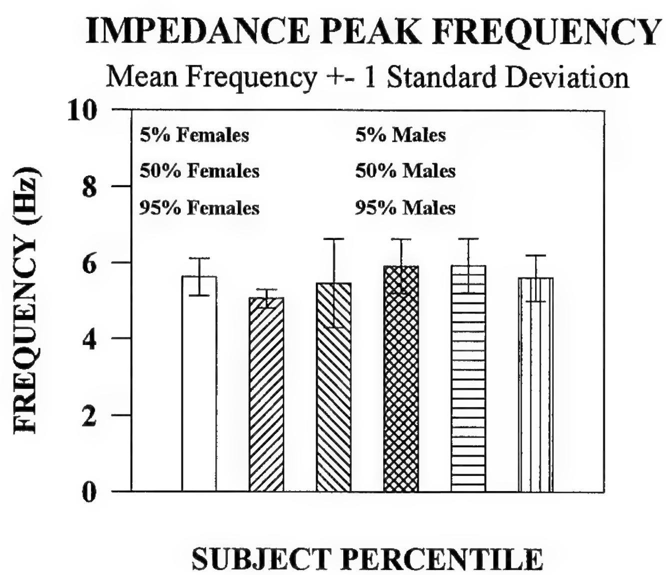


Figure 4 Group Means for the Impedance Peak Frequency

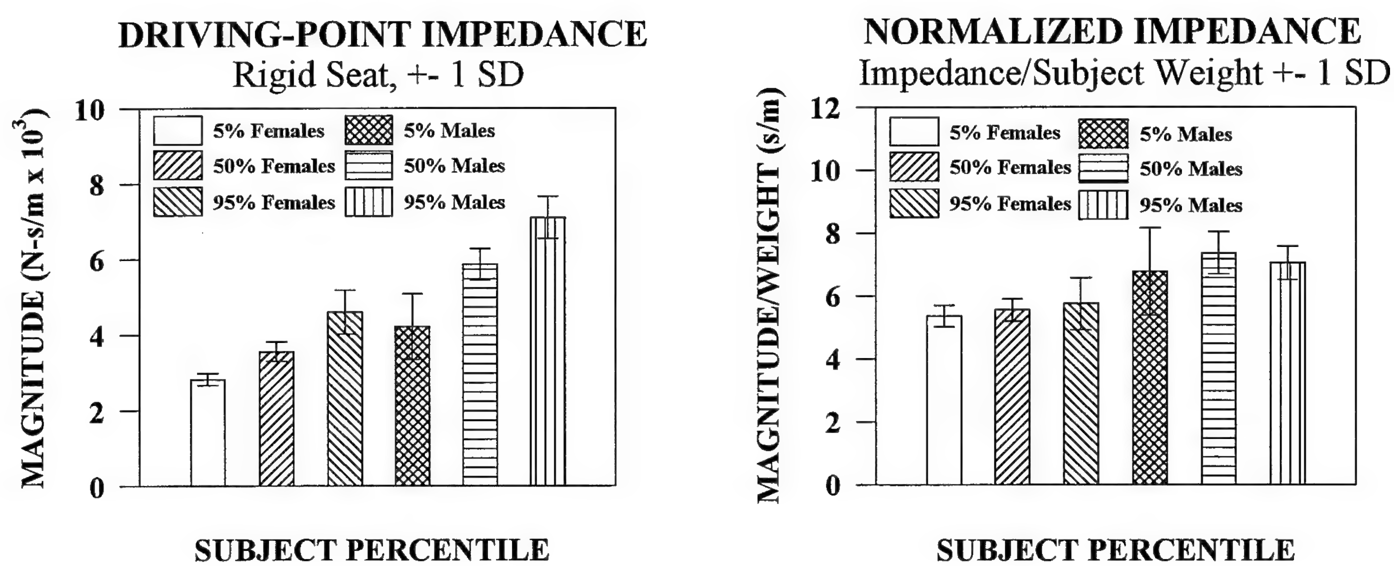


Figure 5 Primary Peak Means for Impedance and Normalized Impedance - Rigid Seat Configuration

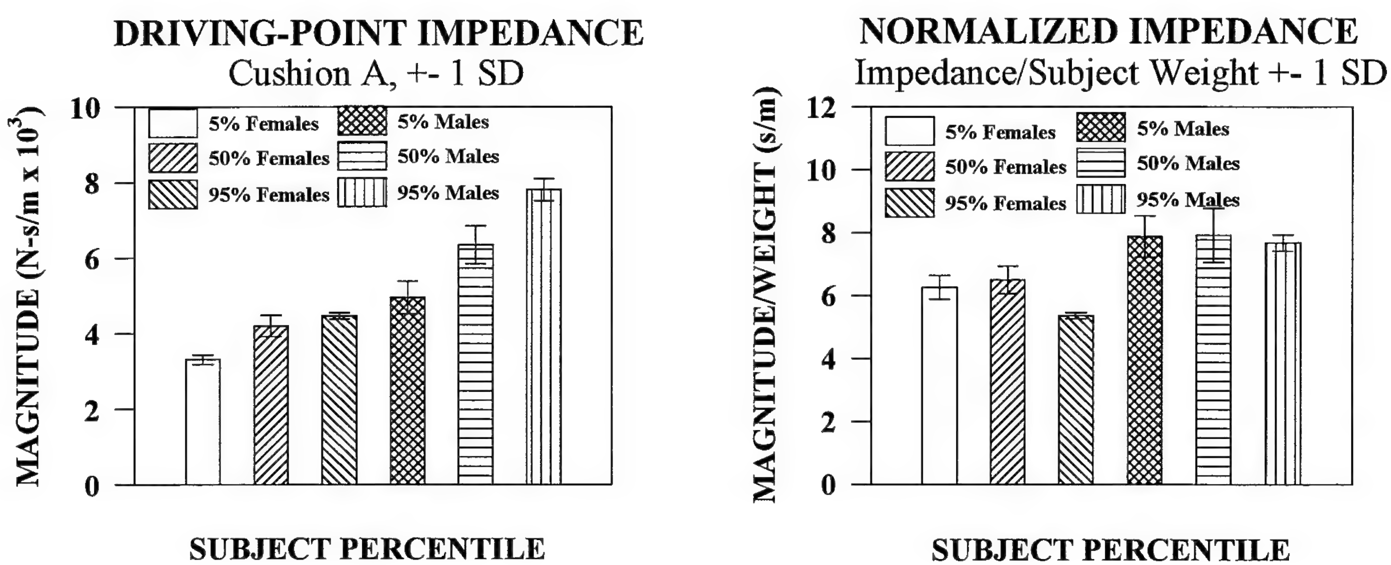
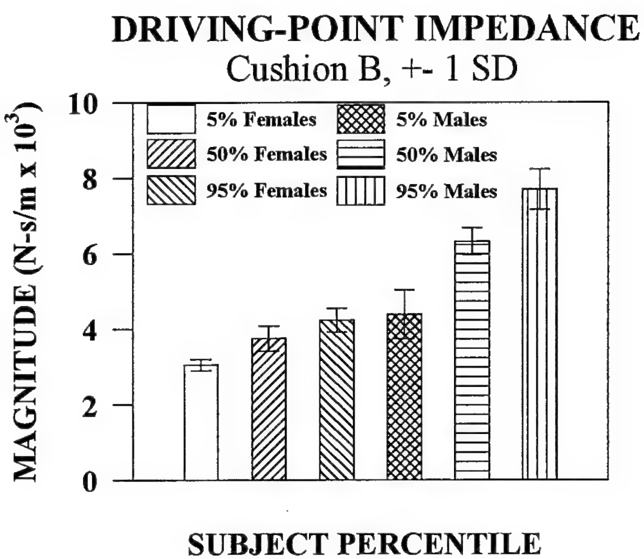


Figure 6 Primary Peak Means for Impedance and Normalized Impedance - Cushion A Configuration



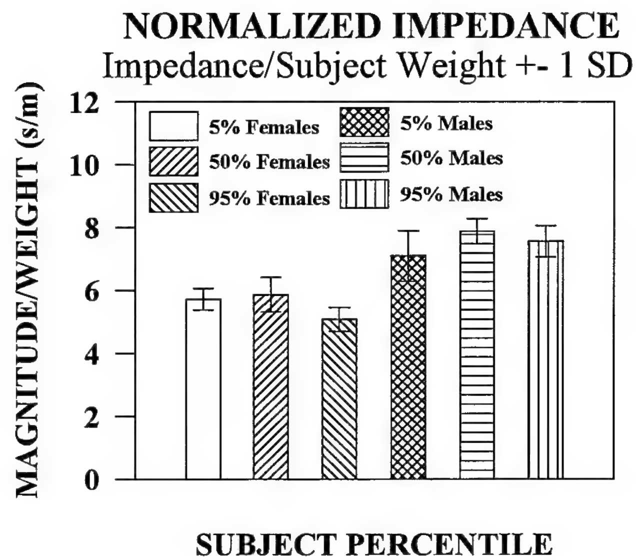


Figure 7 Primary Peak Means for Impedance and Normalized Impedance - Cushion B Configuration

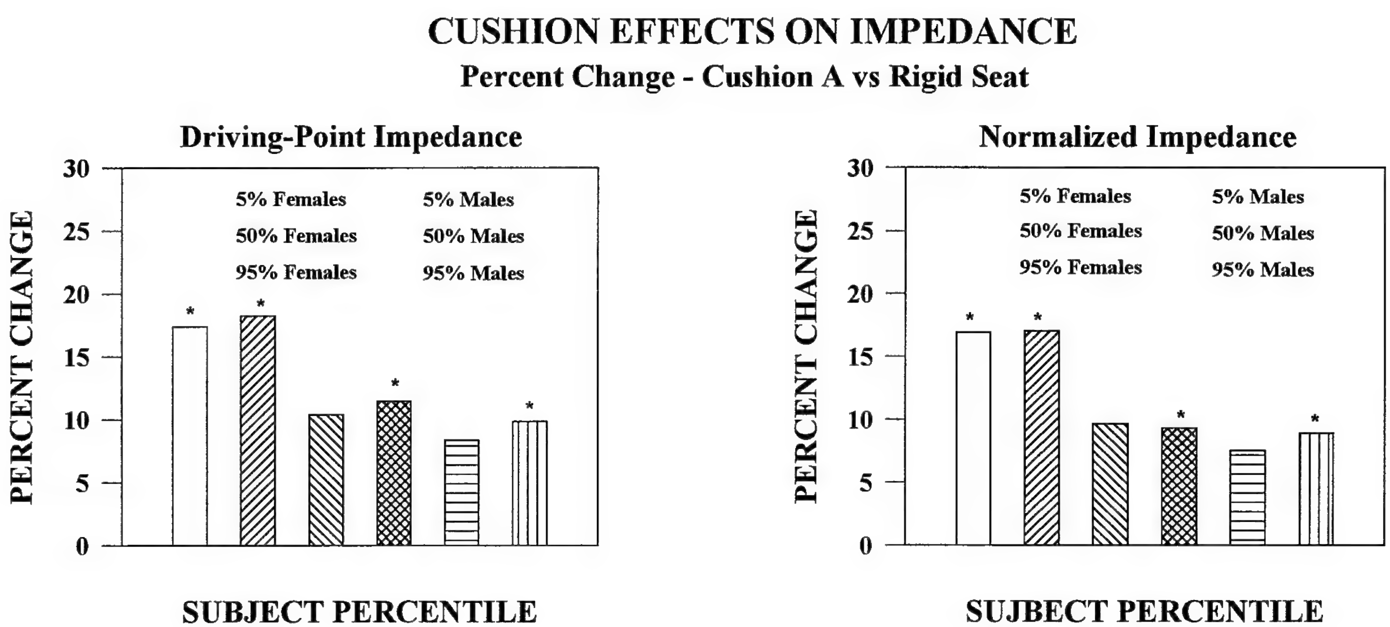


Figure 8 Percent Change in Primary Peak Means for Impedance/Normalized Impedance Using Cushion A as Compared to the Rigid Seat Configuration

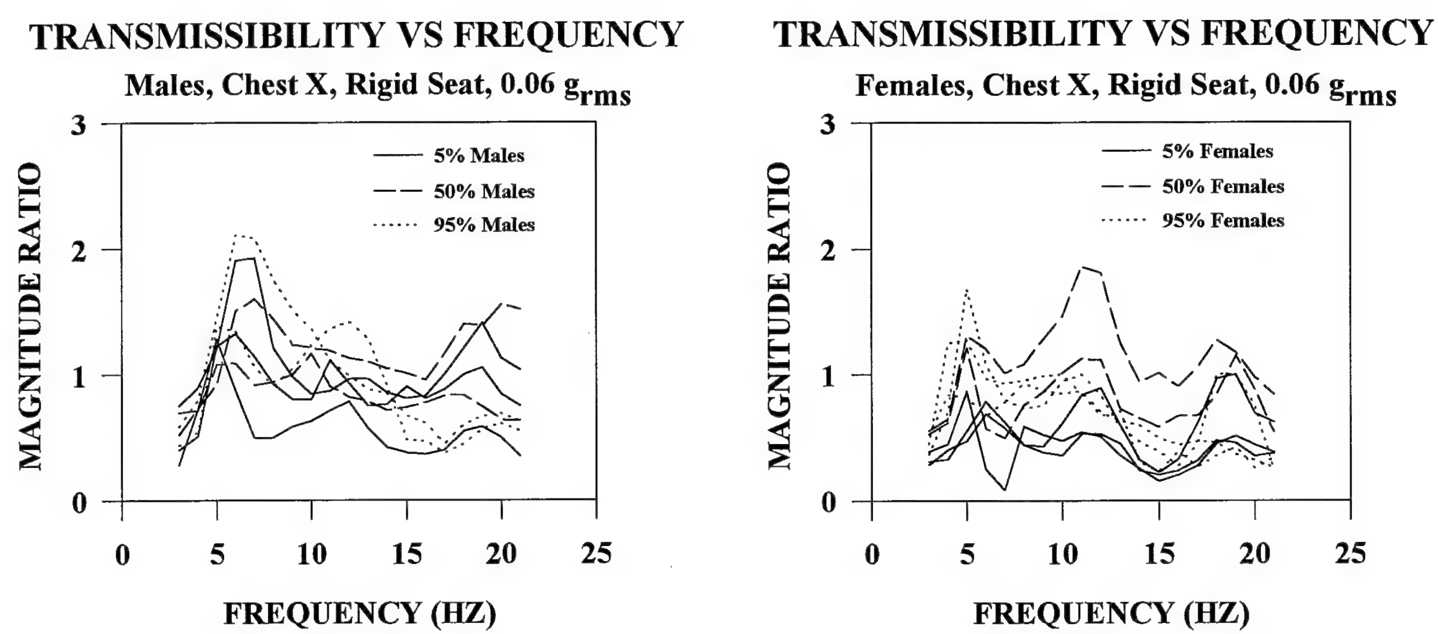


Figure 9 Horizontal Chest Transmissibility Responses

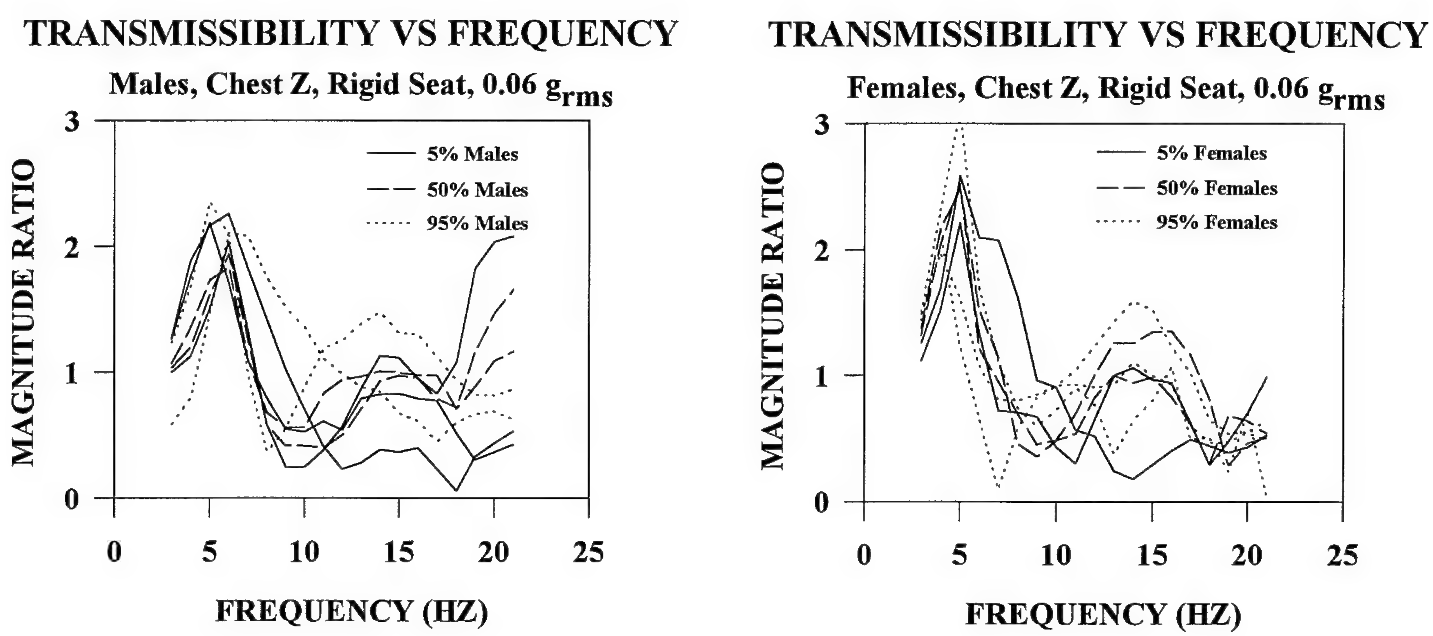


Figure 10 Vertical Chest Transmissibility Responses

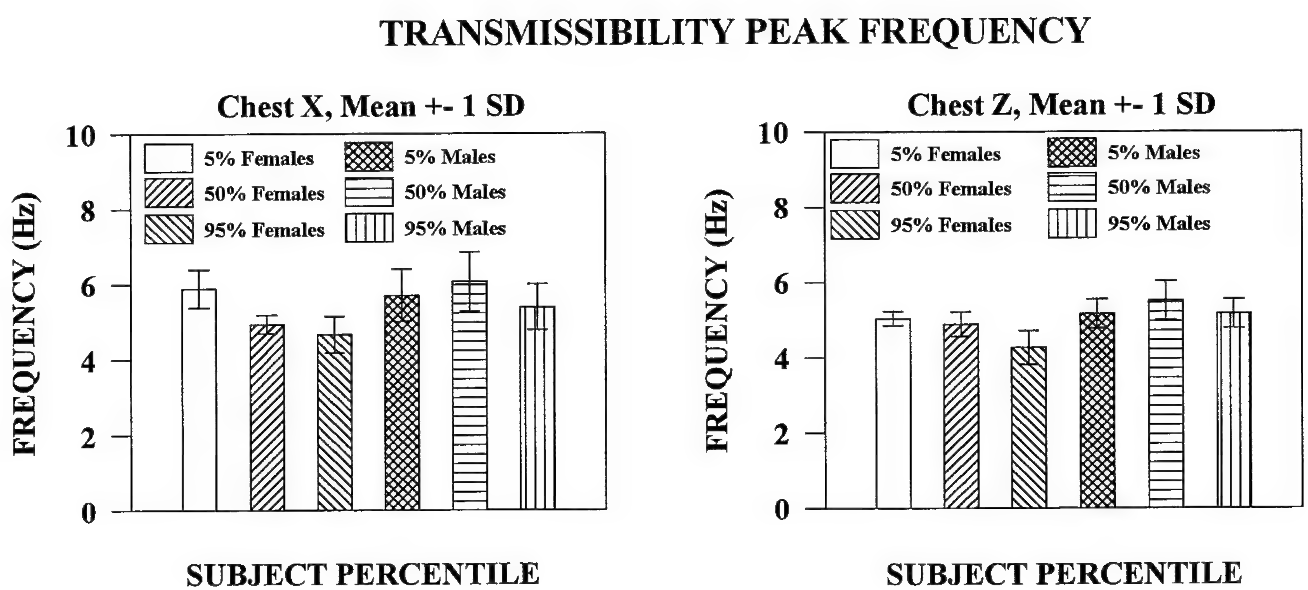
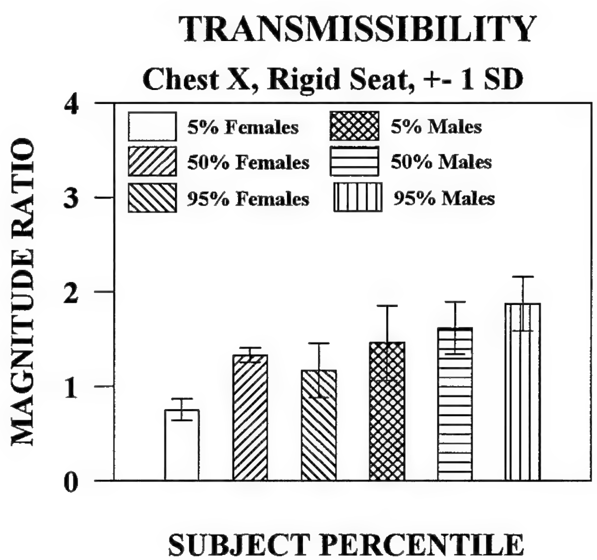


Figure 11 Group Means for the Transmissibility Peak Frequency



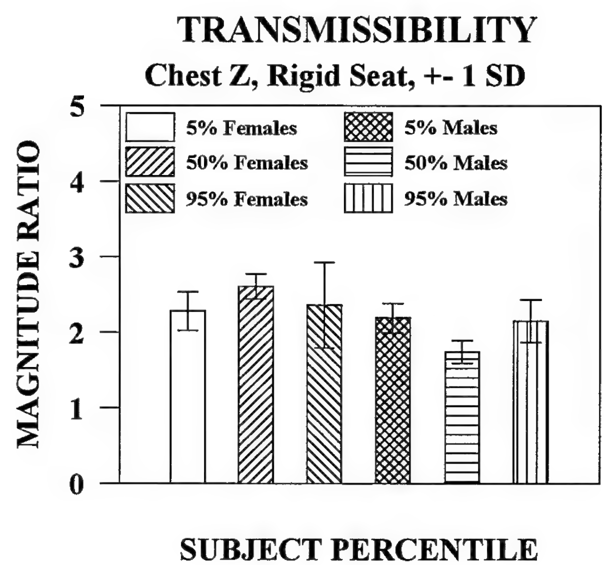


Figure 12 Primary Peak Means for Chest Transmissibilities - Rigid Seat Configuration

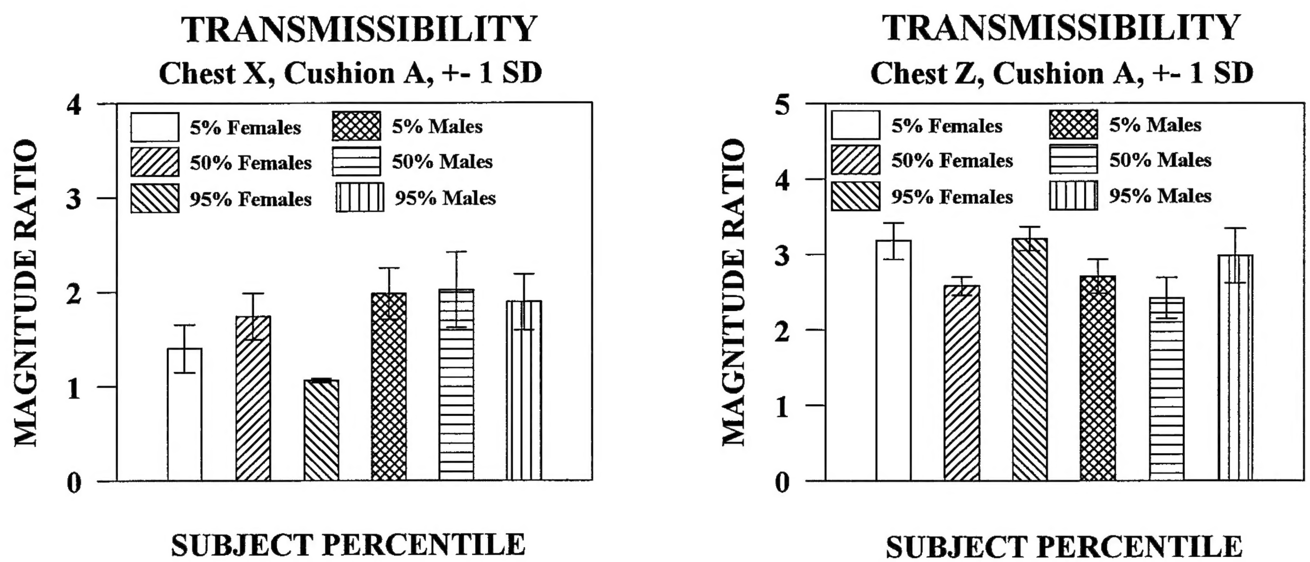
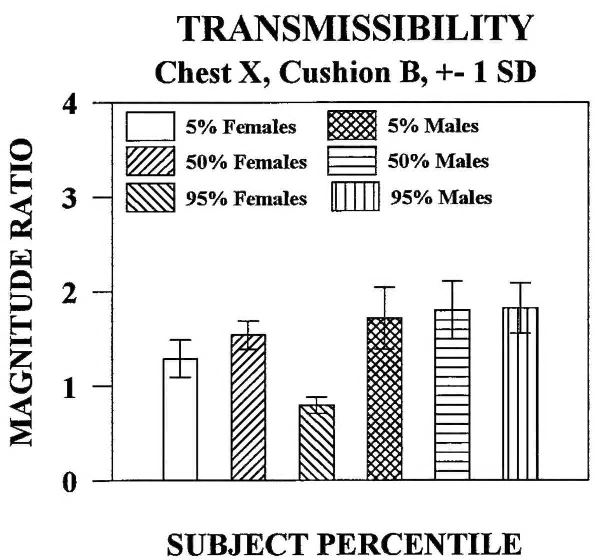


Figure 13 Primary Peak Means for Chest Transmissibilities - Cushion A Configuration



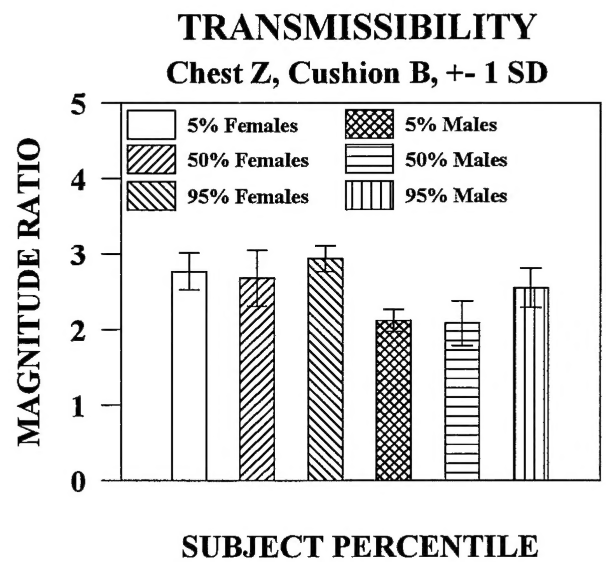


Figure 14 Primary Peak Means for Chest Transmissibilities - Cushion B Configuration

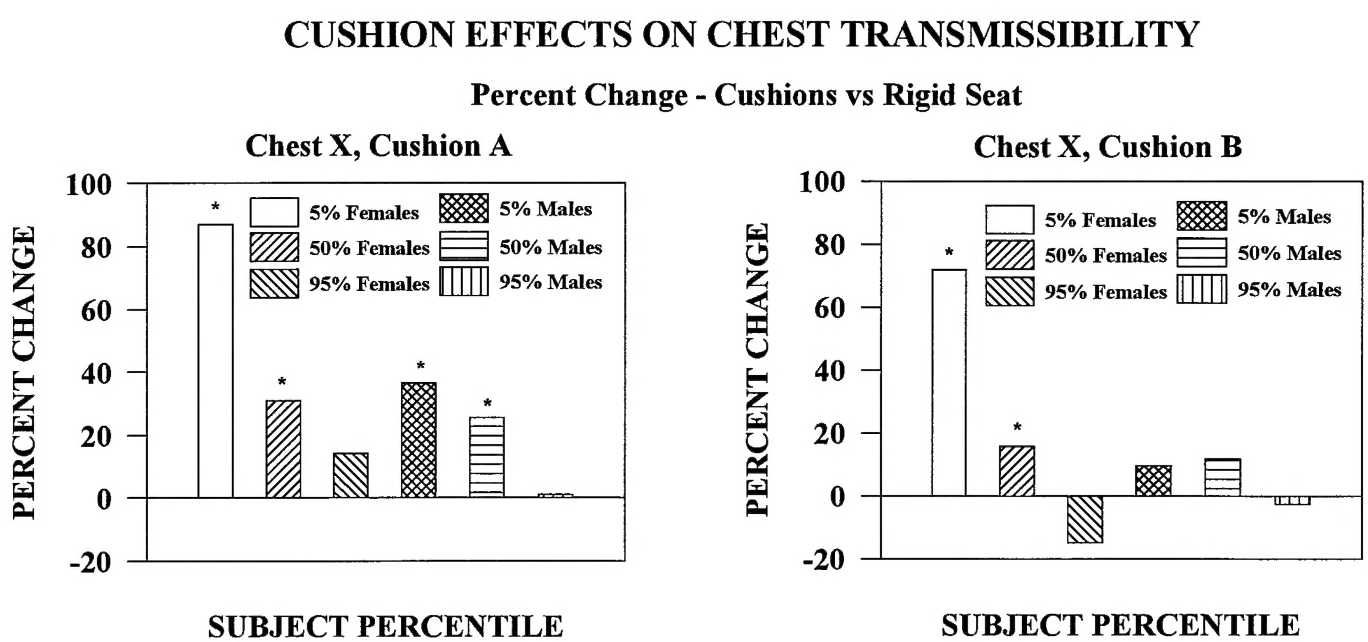


Figure 15 Percent Change in Primary Peak Means for Horizontal Chest Transmissibility Using Cushions as Compared to the Rigid Seat Configuration

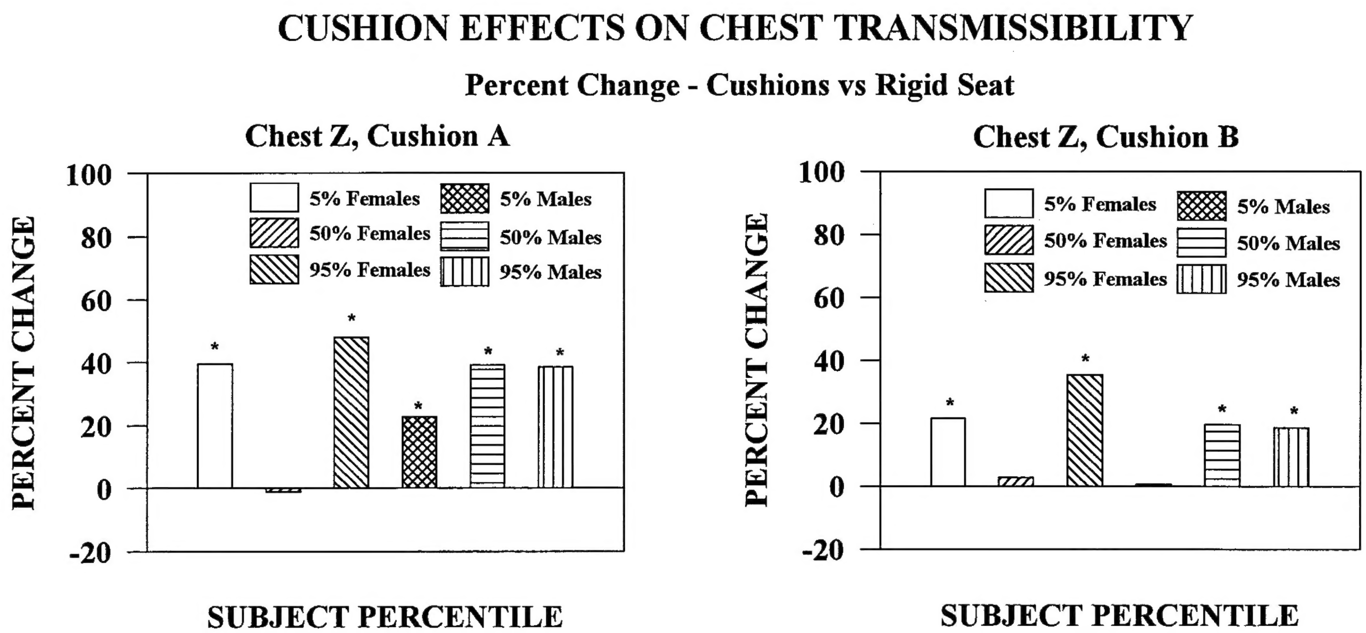


Figure 16 Percent Change in Primary Peak Means for Vertical Chest Transmissibility Using Cushions as Compared to the Rigid Seat Configuration